ARMY RESEARCH LABORATORY

Electrical Vehicle Stopper Evaluation Phase III—Nonlethal Technologies, Inc.

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Electrical Vehicle Stopper Evaluation Phase III—Nonlethal Technologies, Inc.

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Sensors and Electron Devices Directorate

Sponsored by

National Institute of Justice

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Abstract

This report discusses the results of phase III of the Electrical Vehicle Stopper Evaluation (EVSE) program of the Nonlethal Technologies, Inc., Road Sentry vehicle stopper device. The Road Sentry injects a large current pulse directly into the underside of the vehicle and stops the vehicle by damaging the electrical components. This report also discusses the field evaluation of safety, ease of use, and effectiveness of the device.

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1. Introduction

The U.S. Army Research Laboratory (ARL) and the National Institute of Justice (NIJ) conducted an evaluation of contractor-developed devices that are claimed to stop vehicles in a nonlethal manner. This evaluation was conducted under a four-phase program, called the Electrical Vehicle Stopper Evaluation (EVSE) program. In phase I, a Commerce Business Daily (CBD) notice was posted that requested submissions of proposed concepts or devices to electrically stop commercial vehicles. Phase II consisted of a laboratory evaluation of a subset of the concepts or devices on a chassis dynamometer. (A chassis dynamometer is a set of rollers on which the vehicle's drive wheels are placed, and the vehicle can be driven with a remote control at highway speeds.) Phase III, described in this report, is a field test evaluation of vehicles on a roadway. Phase IV will be an evaluation conducted by law enforcement personnel.

Phase I was documented in the report *Electrical Vehicle Stopper Evaluation—Phase I* by Berry and Brisker [1]. Phase II for Nonlethal Technologies (NLT), Inc., was documented in the report *Electrical Vehicle Stopper Evaluation—Nonlethal Technologies, Inc.*, by Turner and Kaplan [2]. The overall phase II report was the *Electrical Vehicle Stopper Evaluation—Phase II Final Report* by Berry et al [3].

The EVSE program is being conducted so that law enforcement agencies can end high-speed chases and protect public and military facilities. In the phase II laboratory experiments, NLT participated in the evaluation under its own internal funding. For phase III, the NIJ funded NLT for field test participation.

We conducted the phase III field test at the Maryland Police and Correctional Training Commission's Driver Training Facility in Sykesville, MD. The site has two track test areas in which the test series was conducted. The first test area is a large (approximately 1 mi) loop track. A drawing of the highway track is shown in figure 1. The track is paved and has a long straight section (speeds up to 90 mph can be obtained on the straight section). The track also has short straight sections of roadway inside the track, which simulate highway exit and entry ramps. The second test area is a city-type arrangement. A drawing of the city area is shown in figure 2. The city track contains curbing, streetlights, stop signs, etc.

In this evaluation, ARL, NIJ, and NLT together conducted the experiments. NLT was responsible for providing its device (Road Sentry) and personnel to operate its device, drive the vehicles, and consult on the test runs. The test plan for the experiments is outlined in appendix A. Deviations from the test plan occurred during the experiments, because of device failures and preliminary results of the test runs. The NLT device was tested against 16 vehicles. The vehicles are listed in table 1. A contract mechanic repaired and

examined the vehicles in the local area of the test site before the test period. The mechanic also examined and repaired the vehicles after the test series to determine the damage created by the device.

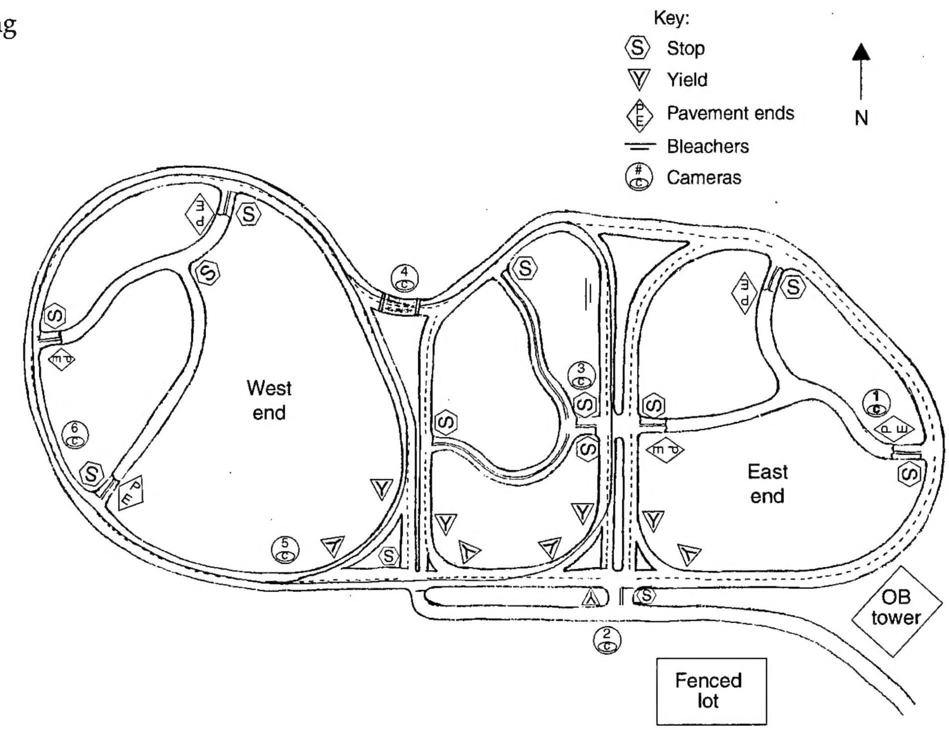


Figure 1. Driver training facility highway track.

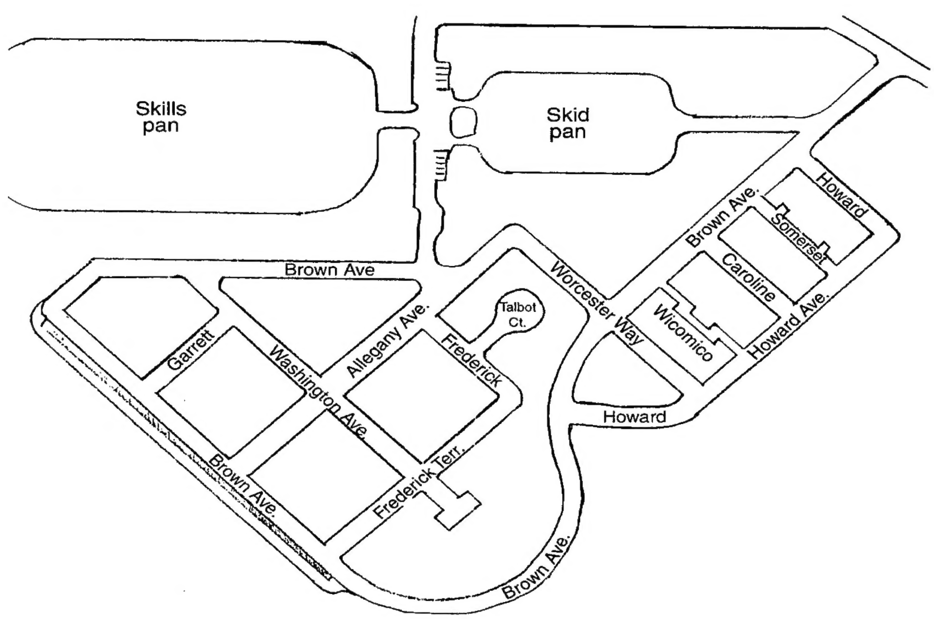


Figure 2. Driver training facility urban track.

Table 1. Test vehicles.

Model year	Manufacturer	Model
1994	Hyundai	Excel
1989	Jeep	Cherokee
1993	Ford	Probe
1989	Dodge	Spirit
1994	Toyota	Tercel
1994	Pontiac	Grand Am
1992	Plymouth	Grand Voyager
1990	Nissan	Pathfinder
1990	Nissan	Maxima
1993	Ford	Aerostar (white)
1995	Chevrolet	Blazer
1993	Chevrolet	Silverado pickup truck
1991	Honda	Accord EX
1991	Pontiac	Firebird
1992	Ford	Aerostar (green)
1991	Ford	Taurus

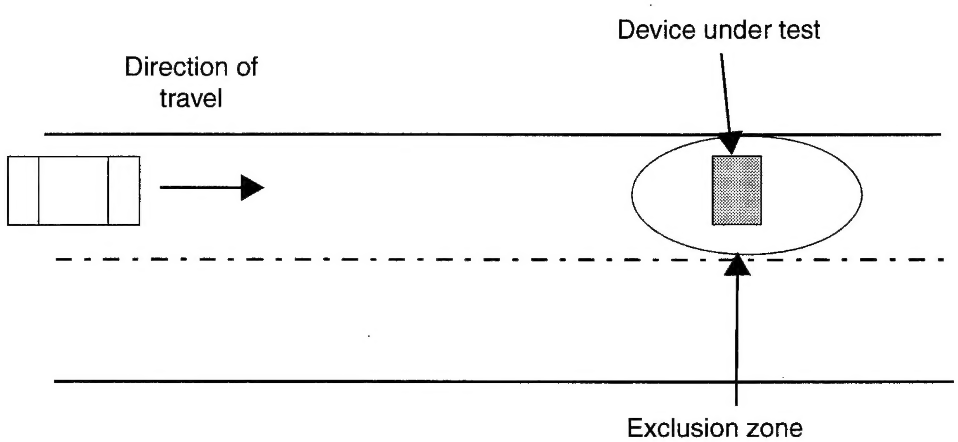
2. Description of Experiment

The NLT field test evaluation was conducted from 22 to 24 May 2000. Sixteen vehicles were tested in the evaluation. Fifty-one shots were fired during the test period (NLT's device was tested in 42 vehicle runs; although 37 actual shots were fired on vehicles, the other shots were either system misfires or field-mapping shots). The evaluation results are discussed in terms of the first shot on a vehicle, because in a real-world scenario, only one shot would be fired on a vehicle. All the subsequent shots on a vehicle are also documented. Shots after the first shot (on vehicles with stumbles or soft kills) were conducted to change electrodes in the Road Sentry to obtain a hard kill. During the subsequent shots, NLT personnel changed electrodes to obtain a better connection to the vehicle. The test layout is shown in figure 3.

As figure 3 depicts, the vehicles were driven over the test device. Since the reaction of the vehicle and driver could not be predicted beforehand, a safety zone was set up around the test device. This safety zone was hyperbola-shaped (using orange traffic cones) to keep people away from the device and the vehicle's path. We used three test scenarios during the test period: constant speed, standing start, and wet device. The scenarios were chosen because they answer law enforcement's need to end high-speed chases (constant speed), stop vehicles at border check points (standing start), and use the device in all weather conditions (wet device). The behavior of the vehicle electronics in the three scenarios should not be different.

For the constant speed scenario, we tested vehicles at a variety of speeds from 20 to 64 mph. Each vehicle was accelerated to a specific speed and driven over the test device. If the vehicle survived the experiment, it was used for a second run. We measured the vehicle speed using the vehicle's speedometer and up to three *X*-band SpeedChek Personal Sports Radars (in some cases, the speedometer did not work, so the SpeedChek was used to verify vehicle speed).

Figure 3. Experimental layout for direct injection field test.



Several vehicles were used for this experimental series for the standing-start scenario. Vehicles were stationed approximately 45 ft from the stopping test device and were accelerated from a standing start and driven over the device. The speed at the test device was measured with the SpeedChek Personal Sports Radars. The maximum vehicle speed of up to 20 mph could be obtained in the standing-start test (even for vehicles with a high acceleration rate).

In several runs of the wet direct injection device scenario, the NLT Road Sentry was tested to determine if it was affected by rain. There was rain during the test period, so we tested the vehicle, device, and track while they were wet.

Field measurements were to be taken inside and outside of the vehicle during the test period. During some of the test runs, a field probe was placed near the direct injection device to determine the radiated field levels near the device (at 5 and 10 ft from the device) to which a pedestrian might be exposed. Internal measurements were taken on one vehicle (a vehicle that survived being exposed to the Road Sentry). The vehicle was parked over the direct injection device and was pulsed. The same field probe that was used in phase II was used to measure the field levels inside the vehicle at each passenger position. (Extensive field measurements were taken during phase II and are discussed in detail in past reports [2,3].) All the phase III experiments were documented with video as well as with a digital camera.

Four types of effects on vehicles are noted in the results. The first is no effect, which means the Road Sentry did not affect the vehicle. The second effect is a stumble, which is a momentary response that lasts as long as the interaction between the Road Sentry and the vehicle. The third effect is a soft kill, which means the vehicle engine is stopped but can be restarted by either a hot restart (key not turned off first) or by resetting the key (key cycle). A soft kill may be able to be restarted even with the vehicle still rolling. The interpretation as to whether a soft kill would stop a high-speed chase is left to the law enforcement community. The fourth effect is a hard kill, which means the vehicle is stopped and cannot be restarted.

3. Description of Device

NLT, Inc., proposed a technique to stop moving vehicles, which involved the direct injection of electrical current into the subframe and engine of the vehicle. The Road Sentry is depicted in figure 4 (surface-gap device). The device is in the prototype stage of development (up to approximately a dozen devices have been produced thus far). The two electrodes (negative and positive) touch the subframe and engine and transmission of the car. When a connection is made, the device initiates an electrical discharge to the subframe and engine and transmission, delivering current into the vehicle. The current upsets or damages the vehicle electronics and stops the vehicle.

Four versions of the Road Sentry were brought to the field test. The first device was a radio-controlled device with an internal inductor to bleed off direct current (dc) components of the pulse (for safety at the electrodes). (This device runs at a pulse rate of about 100 Hz.) This first device did not work at the test site and was not successfully tested against a vehicle. The second device (fig. 4) was radio-controlled with an external surface spark gap to bleed off the dc components of the output pulse (this device runs at a pulse rate of about 100 Hz). The surface spark gap caused a very loud arc noise as the unit fired. Both radio-controlled devices had internal batteries to power the unit. The third device (fig. 5) was powered by a 12-V car battery and was controlled with a direct-wired switch (this device only fires when contact is made between the two electrodes). The fourth device was powered by a 120-V generator and was controlled with a direct-wired switch. (This device is similar to that shown in fig. 5 and only fires when contact is made between the two electrodes.)

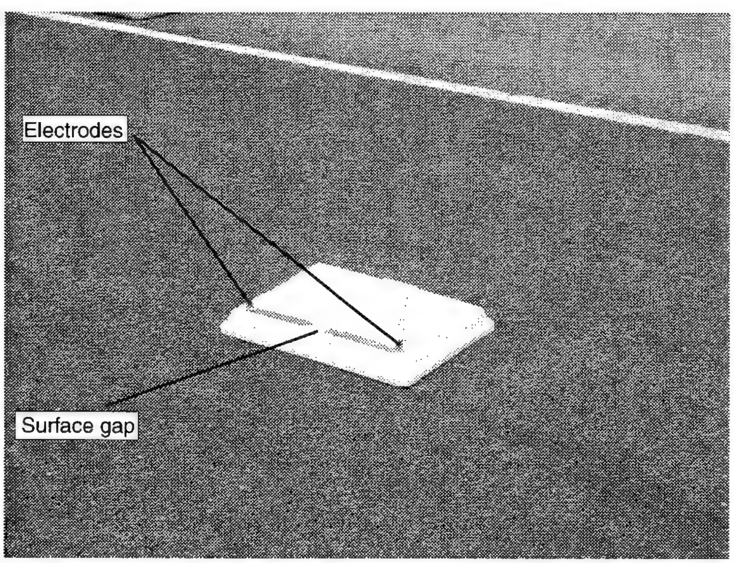
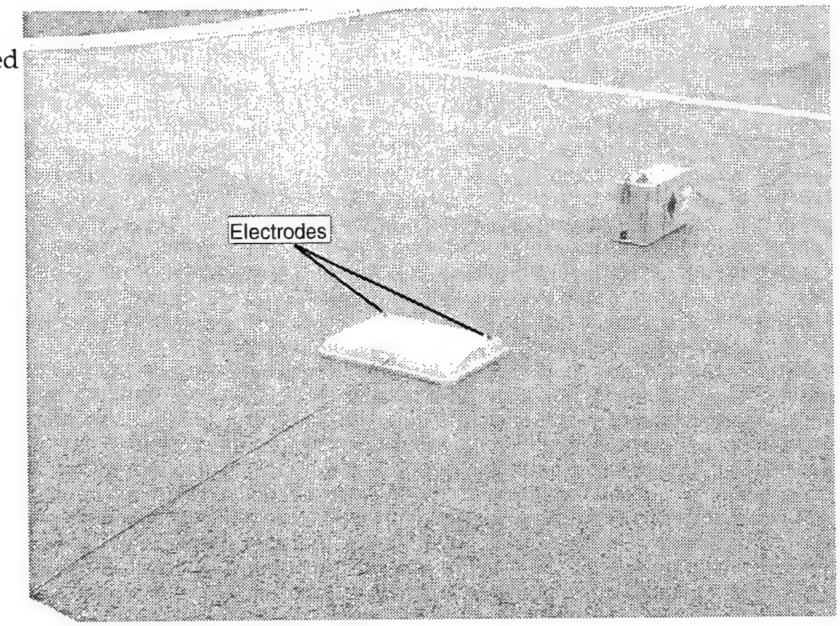


Figure 4. NLT Road Sentry, surface-gap device.

Figure 5. NLT Road Sentry, battery-powered device.



The Road Sentry is a stationary one-man-lift portable device that is activated by an operator just before a vehicle passes over the device. It is hoped that the spring-loaded Sentry electrodes, depicted in figure 4, will contact the vehicle between the frame and the engine as the vehicle passes, causing current to be induced in electrical components of the engine. The Road Sentry was brought to the field test with three sets of probes, the first for car heights (spring wire, 6-in. probes), the second for truck heights (springs that go between the device and the spring wire, 6-in. probes, providing 10 in. of height), and the third for both car and truck heights (1-ft wire and screen probes). According to NLT personnel, the production version of the device will probably have one set of probes for all vehicles. NLT claims that the output of the Road Sentry is +100 kV on one electrode and –50 kV on the other, at a 100-Hz repetition rate (the internal battery-powered devices run at 100 Hz, and the external battery and generator devices only fire when the vehicle is over the device).

4. Human Hazard

According to NLT personnel, the test device output (all four versions) was unchanged from the device laboratory evaluation in phase II [2]. In phase III, a small number of external field maps were conducted during the Dodge Spirit test runs at a distance of 5 and 10 ft. The field levels were quite small (below the noise floor of the measurement system that was used). (Another set of measurements should be conducted with better diagnostics.) Internal measurements were made on the Nissan Maxima. The field measurements again were quite small and could not be measured with the equipment brought to the test site.

In phase II, internal field levels were measured with the device and vehicle on a chassis dynamometer. The field measurements showed field levels inside the vehicle that were below safety standards described by Turner and Kaplan [2].

In the second field evaluation of phase III (Jaycor [4]), it was found that with the device in an outside environment, the field levels produced were dramatically below those measured in phase II (even though the device output had been increased). The field levels in phase II were much higher because they were measured in a metal room with the test device on a large metal dynamometer. This would imply that the field levels from the NLT Road Sentry would also be much lower than those measured in phase II. Thus, the test device does not pose a human health hazard (with respect to radio frequency emissions) for the driver, passengers, or pedestrians.

5. NLT Road Sentry Experimental Results

Sixteen vehicles were tested in the test series with 37 shots fired on the vehicles. For the full shot record for the test period, see appendix B. During the test period, several vehicles were tested wet, since during the first day of testing, heavy rain had fallen and the track was wet. The wet device was the second radio-controlled unit with the surface gap. The radio-controlled device with surface gap is designed to create an arc between the two electrodes of the surface gap. Once the gap breaks down, the water between the electrodes is burned off. There was no difference between a wet device, vehicle, or track and a dry device, vehicle, or track. Table 2 shows the results of the NLT field test.

Table 2. Vehicle damage.

Model year	Manufacturer	Model	Damage
1994	Hyundai	Excel	Distributor
1989	Jeep	Cherokee	Ignition-control module, engine-control module (ECM)*
1993	Ford	Probe	EEC,* ignition-control module, ignition sensor (distributor)
1989	Dodge	Spirit	Radiator fan motor, engine-control computer single-module engine controller (SMEC)*
1994	Toyota	Tercel	Manifold absolute pressure sensor
1994	Pontiac	Grand Am	Ignition-control module
1992	Plymouth	Grand Voyager	None
1990	Nissan	Pathfinder	None
1990	Nissan	Maxima	None
1993	Ford	Aerostar (white)	EEC, ignition-control module
1995	Chevrolet	Blazer	None
1993	Chevrolet	Silverado pickup truck	Power-train control module (PCM),* ignition-control module, distributor pickup
1991	Honda	Accord EX	None
1991	Pontiac	Firebird	Alternator
1992	Ford	Aerostar (green)	EEC
1991	Ford	Taurus	EEC, ignition-control module

*The engine-control computer has different names by different manufacturers. The engine-control computer is known as the engine-control unit (ECU) by Japanese manufacturers, the electronic-engine control (EEC) by Ford, power-train control module (PCM) by General Motors, and the single-module engine controller (SMEC) by Chrysler. They refer to the same functional part.

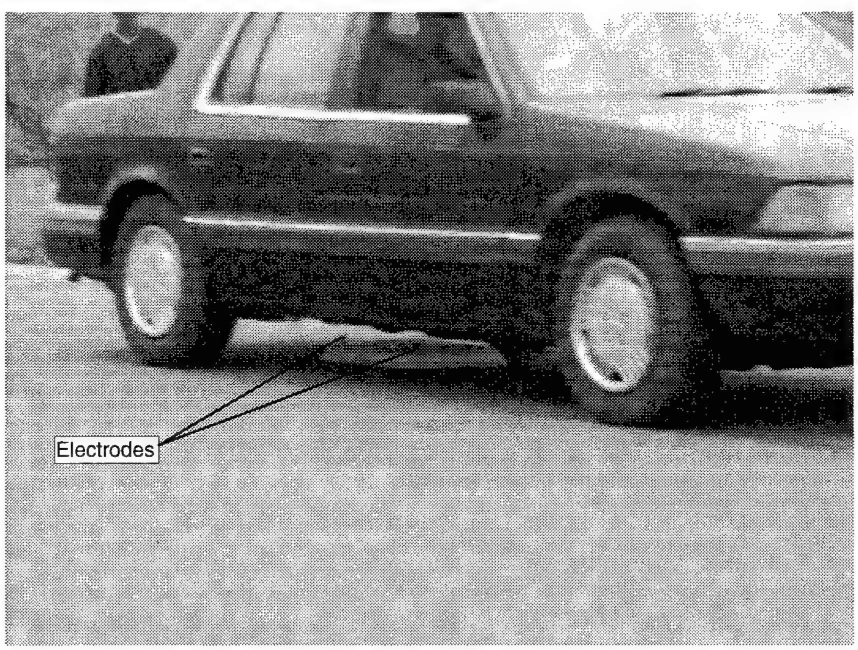
The Hyundai Excel was damaged in shot 2 (hard kill) (in shot 1, the device did not fire) at 64 mph with the surface-gap device, with 6-in. probes. The Excel suffered damage to its distributor (the ignition sensor inside).

The Jeep Cherokee was damaged (hard kill) (shot 3, the only shot) at 60 mph with the surface-gap device, with 10-in. electrodes. The Jeep was tested with the track, vehicle, and device damp. The Jeep suffered damage to the electronic-control module (ECM) as well as the ignition-control module.

The Ford Probe was stopped with no restart (hard kill) (shot 4, the only shot) at 60 mph with the surface-gap device in a damp car, track, and device configuration. The Ford Probe suffered damage to the electronic-engine control (EEC), the electronic-ignition sensor in the distributor, and the ignition-control module. Six-in. probes were used against the Ford Probe.

The Dodge Spirit was tested at 20, 40, and 60 mph and in a standing-start configuration (shown in fig. 6). On the first shot (shot 5), the Dodge Spirit was not affected in a standing-start configuration. In the subsequent shots, including standing start (four shots) and 20- and 60-mph configurations, the vehicle was not stopped (no effect). It was however damaged (hard kill) during a 40-mph run. In each case, the car, track, and device were dry. All the slow-speed runs were conducted with the 12-V device, and the faster runs (40 and 60 mph) were conducted with the generator-powered device and with the 6-in. and 1-ft probes. Because the vehicle was not stopped in the standing-start configuration and at 20 mph, the results may show evidence that the Road Sentry may have difficulty with slower moving vehicles (although it only stumbled at 60 mph and did not stop). In the last shot, the vehicle suffered damage to the radiator fan motor and the engine control computer (single-module engine controller (SMEC)).

Figure 6. Vehicle passing over Road Sentry.



The Toyota Tercel was tested in a standing-start configuration and at 35 and 40 mph with the use of the 12-V device, with 6-in. electrodes. In the first shot at 35 mph (shot 11), the Tercel stumbled and was not stopped (soft kill) (the engine dropped to an idle and then recovered with a restart). In all the subsequent shots, the Tercel lost power and stumbled but did not stop. At the end of the test runs, the vehicle could not drive faster than 15 mph because of electronic damage. The Tercel suffered damage to the manifold absolute pressure (MAP) sensor.

The Pontiac Grand Am was damaged (hard kill) (shot 15, the only shot) at 55 mph with the use of the 12-V device, with 6-in. electrodes. The Grand Am suffered damage to the ignition-control module.

The Plymouth Voyager was tested in a standing-start configuration and at 20 and 55 mph with the use of the 12-V-powered device, with 6-in. electrodes. The vehicle was stopped (soft kill) in all configurations, including the first shot (shot 16). It suffered no major damage during the testing.

The Nissan Pathfinder was tested at 34 and 49 mph with the generator-powered device, with 6-in. electrodes. On the first shot, the Pathfinder was stopped (soft kill) at 49 mph (shot 20). On the second shot, it lost power (stumble) at 34 mph.

The Nissan Maxima was stopped (soft kill) (shot 22, the only shot) with the generator-powered device, with 6-in. probes. The Maxima suffered no damage.

Two Ford Aerostars (green and white) were tested with the generator-powered device. Both were tested in the standing-start configuration, and one was tested at 56 mph. The green Aerostar was damaged (hard kill) (shot 41, the only shot) in the standing-start configuration and the other (white Aerostar) had a soft kill (restarted after key reset on the first shot (shot 23)). After the standing start on the white Aerostar, it was tested and damaged (hard kill) at 56 mph. In both runs, the vehicles were tested with a dry track and device, with 6-in. probes. The green Aerostar suffered damage to the EEC, and the white Aerostar suffered damage to the EEC and the ignition-control module.

The Chevy Blazer was tested at 38, 58, and 63 mph and in a standing-start configuration with the generator-powered Road Sentry in a dry configuration. On the first shot (shot 25) in the standing-start configuration, the Blazer stumbled and did not stop. The Blazer was not stopped (no effect) at 63 mph or in the standing-start configuration. At 38 and 58 mph, the vehicle was stopped but could be restarted with a key cycle. The standing-start test results may imply that the NLT device may have difficulty with a vehicle that is moving slowly over the device. It also could show that the variation in response with speed is due to where the device hits under the vehicle. The vehicle suffered no damage.

The Chevy Silverado pickup truck was stopped with no restart (hard kill) (shot 32, the only shot) at 60 mph in a dry configuration with the generator-powered device. The vehicle suffered damage to the power-train control module (PCM), the ignition-control module, and the distributor pickup.

The Honda Accord EX was tested in the standing-start configuration and at 40, 59, and 61 mph. During the first shot (shot 33), the Honda was stopped only during the 61 mph run (soft kill—it restarted with a key cycle). It also stumbled (no stop) during the other runs. We tested the car dry with 6-in. probes and the generator-powered device. Because of the results at all speeds except the 61-mph run, this vehicle shows evidence that the Road Sentry may have difficulty stopping vehicles that are running at slower speeds. The Accord EX suffered no damage.

The Pontiac Firebird was tested in the standing-start configuration as well as at 38, 56, and 60 mph with the generator-powered device, with 6-in. electrodes. In the first shot at 56 mph (shot 37), the vehicle was stopped (soft kill). In the subsequent runs, it stumbled in the standing-start configuration and at 38 and 60 mph. It suffered damage to the alternator.

The Ford Taurus was stopped with no restart (hard kill) at 59 mph (shot 42, the only shot), dry, and with the generator-powered device, with 6-in. probes. The Taurus suffered damage to the EEC as well as the ignition-control module.

6. Conclusions

Sixteen vehicles were tested during the evaluation of the Road Sentry. The first shot taken on a vehicle is considered to be the shot that is most relevant to the evaluation. All subsequent shots are mentioned but should not be considered for determining how the Road Sentry performed in the evaluation. Of the 16 vehicles tested, 7 suffered hard kills (43.7%), 7 suffered soft kills (43.7%), 1 vehicle stumbled (6.3%), and 1 vehicle was not affected (6.3%). For some of the vehicle tests, the contractor checked the vehicle height and installed the proper electrodes for that particular vehicle before the vehicle run.

If a hard kill was not obtained, NLT personnel were given the opportunity to try adjusting their system to obtain a hard kill (by changing electrodes or other adjustments). Some of the vehicles were sent over the device multiple times with the same or different electrodes installed on the Road Sentry. A total of 37 shots were fired into the 16 vehicles during the test period. Of the 37 shots (these numbers include the first shot on a vehicle), 8 caused hard kills, 16 caused soft kills, 9 caused vehicles to stumble as they crossed the device, and 4 had no effect. Some of the vehicles were subjected to multiple shots (meaning that the damage to them may have been a cumulative effect). For the hard kills, the vehicles were damaged, were not restartable, and needed to be repaired by a mechanic. For some of the soft kills, the vehicles could be restarted while they were still rolling and without turning the key off. Other soft kills required that the key be turned off before the vehicle could be restarted. (The interpretation as to whether a soft kill would end a high-speed chase is left to the law enforcement community and is beyond the scope of this evaluation.) The stumbles would only be a nuisance for the driver and would not dramatically affect the vehicle's performance or stop a high-speed chase. The experiments in both phase II and phase III revealed that the device produces field levels for the driver, passengers, and pedestrians that are below the Institute of Electrical and Electronics Engineers (IEEE), Inc., safety standard [5].

The device was powered by three different configurations: internal battery (with radio control and external surface spark gap), 12-V car battery, and 120-V generator. (A fourth device with an internal inductor was brought but was never tested against the vehicles.) Each of the devices had the same output parameters (according to the staff of NLT). The radio-controlled device and the 12-V-powered device suffered damage to their power inverters (this is probably what also happened to the radio-controlled unit with the internal inductor).

Some improvements to the device may be to develop a multiple probe design so that the chances of hitting the vehicle in the correct location are increased. Also, standardized probes that work on any kind of vehicle and probes that could possibly enhance the arc to the vehicle may improve the performance of the device. A more reliable device with more robust components would be required for production units. The devices used in the field tests were prototypes and damaged components would be expected.

References

1. M. Berry and H. Brisker, *Electrical Vehicle Stopper Evaluation—Phase I*, U.S. Army Research Laboratory, ARL-TN-87 (April 1997).

2. T. Turner and S. Kaplan, *Electrical Vehicle Stopper Evaluation—Nonlethal Technologies, Inc.*, U.S. Army Research Laboratory, ARL-TN-88 (April 1997).

3. M. Berry, T. Turner, G. Tran, C. Lazard, S. Kaplan, and H. Brisker, *Electrical Vehicle Stopper Evaluation—Phase II Final Report*, U.S. Army Research Laboratory, ARL-TR-1374 (May 1997).

4. M. Berry, T. Turner, and C. Reiff, *Electrical Vehicle Stopper Evaluation, Phase III—Jaycor*, U.S. Army Research Laboratory, ARL-TR-2273 (October 2000).

5. *IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields*, 3 kHz to 300 GHz, Institute of Electrical and Electronics Engineers, Inc., IEEE Std C95.1, 1999.

Appendix A. Test Plan for Electrical Vehicle Stopper Evaluation Program, Phase III

A-1. Background

As part of phase II of the Electrical Vehicle Stopper Evaluation (EVSE) program, the U.S. Army Research Laboratory (ARL) evaluated two direct injection and three microwave concepts or devices with respect to effectiveness, ease of use, and safety. These evaluations were conducted in the laboratory on a chassis dynamometer. For phase III, ARL will evaluate systems in the laboratory (if required), as well as in the field. Two contractors responded to the request for proposals (RFP) published by the National Institute of Justice for phase III. Both contractor devices were evaluated at ARL and were found to be safe and effective. According to the first contractor, the device has not changed from the device that was evaluated in phase II. The second contractor's device will have an increased output of about 25 percent. The increase in output should increase the measured field levels by the same factor. With this in mind, we will not need further laboratory evaluation of either contractor's device as the field levels will not increase more than 25 percent (i.e., they are still below relevant standards). During the experimental series, up to 20 vehicles will be used for each contractor's device. Once a vehicle is damaged, attempts will be made to repair the vehicle during the test period.

A-2. Test Location

The field test for phase III will be conducted at the Maryland Police and Correctional Training Commission's Driver Training Facility in Sykesville, MD. The site has two test areas in which the test series may be conducted. The first area is a large (approximately 1 mi) loop track. The track is paved and has several straight sections. (Speeds up to 90 mph can be obtained on the straight section.) The track also has approximately 1/4-mile straight sections in between. The second test area is a city-type arrangement. At the site, available support includes automobile repair shops, gasoline fuel, and generators for powering data acquisition equipment. There are also hotel accommodations within 30 miles.

A-3. Test Period

Each contractor will be given one week to test up to 20 vehicles. The actual number of test runs during that time will depend on the reliability of the contractor-provided test device, the amount and severity of vehicle damage, and the vehicle-repair turnaround time. At this time, the amount of damage or the repair turnaround time cannot be predicted. A minimum of three different vehicles will be used for each test scenario (constant speed, standing start, and wet device).

A-4. Test Layout

The test layout is shown in figure A-1. As the figure depicts, the vehicles will be driven over the test device. Since the reaction of the vehicle and driver cannot be predicted, a safety zone will be set up around the test device. This safety zone will be hyperbola-shaped to keep people away from the device as well as the vehicle path.

A-5. Test Vehicles

Fifteen vehicles will be used during the test series for each contractor. Table A-1 is a template for the planned test series. The vehicles listed in the template are for illustration only (the actual vehicles tested may be different). The effect of the test device on the target vehicle and a detailed list of any vehicle parts damaged will be noted for each test in the series.

Figure A-1. Field test layout.

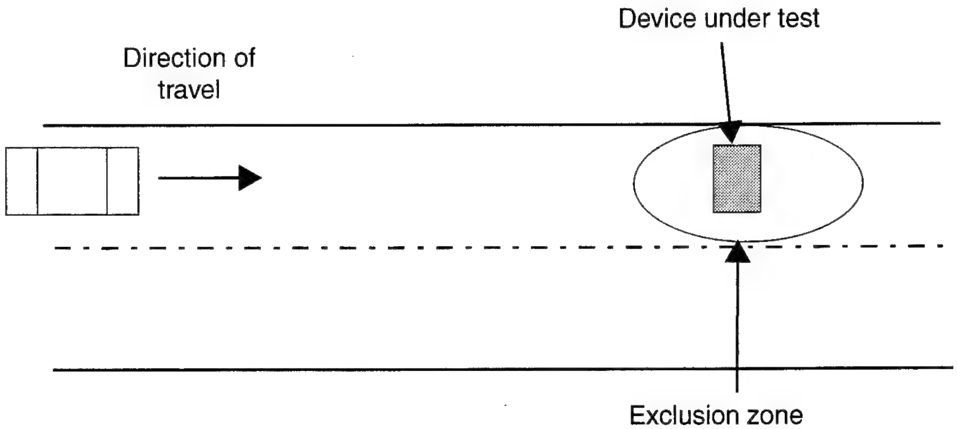


Table A-1. Test plan template.

Vehicle	Standing start	20 mph	40 mph	60 mph
1990 Toyota Corolla				
1988 Toyota Pickup				
1998 VW Jetta				
1987 Mercedes 300E				
1989 Dodge Dakota				
1988 Chevy Blazer				
1989 Ford Probe				
1993 Cadillac Fleetwood				
1990 Ford Taurus SHO				
TBS (additional vehicles)				

TBS = to be specified

A-6. Test Scenarios

A-6.1 Constant Speed

A minimum of three vehicles will be used for each of the speed experiments. The vehicle will be accelerated to 60 mph and will be driven over the device. If the vehicle survives the experiment, a second run will be conducted in which the vehicle will be accelerated to a speed of 40 mph. If the vehicle survives again, it will then be tested at 20 mph. The vehicle speed will be measured with the use of the vehicle's speedometer. If the speedometer is not functional, the speed will be measured with a portable radar speed detector. (At least nine vehicles will be used for the constant speed test series.)

A-6.2 Standing Start

A minimum of six vehicles will be used for this experimental series. The vehicle will be stationed approximately 50 ft from the stopping device and will be accelerated from a standing start and driven over the device.

A-6.3 Wet Direct Injection Device

The devices will be tested to determine if they are affected by rain. Once most of the testing is complete and if it has not rained during the test period (i.e., the device has not been tested wet), the device will be soaked with water. The device self-breakdown will be examined first. The device will be energized to its operating voltage to determine if water causes it to break down. If the device does not break down, then the underside of one test vehicle will be soaked with water and the vehicle will be driven over the device.

A-7. Field Measurements

Once a vehicle is damaged and cannot be easily repaired, it will be used for field measurements. The vehicle will be parked over the direct injection device and will be pulsed. The same field probe that was used in phase II will be used to measure the fields inside the vehicle at each passenger position. It will also be used to measure the fields on the outside of the vehicle at 3, 10, 20, and 50 ft to determine the levels to which a pedestrian or operator may be exposed. The experiments will be documented with video as well as with a digital camera.

Appendix B. Shot Record

Table B-1. lists the full shot record of the 16 vehicles with the Road Sentry vehicle stopper device of the Nonlethal Technologies, Inc., for phase III of the Electrical Vehicle Stopper Evaluation program.

Table B-1. Full shot record of test period.

Shot no.	Vehicle	Device	Comments	Vehicle speed	Conditions	Results	Vehicle damage (repair shop)
1	Hyundai Excel	Radio 1	Device w/internal inductor, 6-in. electrodes	60 mph	Track wet/car wet/ device dry	No pulse out of device.	None
2	Hyundai Excel	Radio 2	Device w/surface gap, 6-in. electrodes	64 mph	Track wet/car wet/ device dry	Vehicle stopped, no restart. Battery cycle, no restart. No spark.	Distributor
3	Jeep Cherokee	Radio 2	Device w/surface gap, 10-in. electrodes (3-in. springs)	60 mph	Track damp/car damp/device dry	Vehicle stopped, no restart. Battery cycle, no restart. No spark.	Ignition-control module, EEC
4	Ford Probe	Radio 2	Device w/surface gap, 6-in. electrodes	60 mph	Track damp/car damp/device dry	Vehicle stopped, no restart. Battery cycle, no restart. No spark.	EEC, ignition-control module, ignition sensor
5	Dodge Spirit	Radio 2	Device w/surface gap, 6-in. electrodes	Standing start	Track dry/car dry/ device dry	No stop, then device failed.	None
6	Dodge Spirit	12-V powered	Cable connected, 6-in. electrodes	Standing start	Track dry/car dry/ device dry	No stop, car stumbled over device. Check engine light on, then reset.	None
7	Dodge Spirit	12-V powered	Cable connected, 6-in. electrodes, shift to pass side	Standing start	Track dry/car dry/ device dry	No fire from device (no stop).	None
8	Dodge Spirit	12-V powered	Cable connected, 6-in. electrodes, shift to pass side	Standing start (14 ft)	Track dry/car dry/ device dry	One pulse, no stop (electrodes too short).	None
9	Dodge Spirit	12-V powered	Cable connected, 1-ft screen electrodes	Standing start (14 ft)	Track dry/car dry/ device dry	No stop.	None
10	Dodge Spirit	12-V powered	Cable connected, 1-ft screen electrodes	20 mph	Track dry/car dry/ device dry	No stop.	None
11	Toyota Tercel	12-V powered	Cable connected, 6-in. electrodes	35 mph	Track dry/car dry/ device dry	Dropped to idle. Service light, restarted then recovered.	None
12	Toyota Tercel	12-V powered	Cable connected, 6-in. electrodes	40 mph	Track dry/car dry/ device dry	Lost power, let off gas, then could maintain 12 mph. Reset key recovered.	None
13	Toyota Tercel	12-V powered	Cable connected, 6-in. electrodes	Standing start (40 ft)	Track dry/car dry/ device dry	Check engine light stays on, no power. Key cycle did not fix.	Manifold absolute pressure sensor
14	Dodge Spirit	12-V powered	Cable connected, 1-ft screen electrodes	Field map	Track dry/car dry/ device dry	None	None
15	Pontiac Grand Am	12-V powered	Cable connected, 6-in. electrodes	55 mph	Track dry/car dry/ device dry	Vehicle stopped. Key and battery cycle, no restart, no ignition.	Ignition-control module
16	Plymouth Voyager	12-V powered	Cable connected, 6-in. electrodes	55 mph	Track dry/car dry/ device dry	Vehicle stopped. No restart (hot start), key cycle, restart. Gauges dead.	None

Table B-1. Full shot record of test period (cont'd).

Shot no.	Vehicle	Device	Comments	Vehicle speed	Conditions	Results	Vehicle damage (repair shop)
17	Plymouth Voyager	12-V powered	Cable connected, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Vehicle stopped. No restart (hot start). Key cycle, restart.	None
18	Plymouth Voyager	12-V powered	Cable connected, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Vehicle stopped. No restart (hot start). Key cycle, restart.	None
19	Plymouth Voyager	12-V powered	Cable connected, 6-in. electrodes	20 mph	Track dry/car dry/ device dry	Vehicle stopped. No restart (hot start). Key cycle, restart.	Gauge damage, no effect on running
20	Nissan Pathfinder	Ac powered	Generator powered, 6-in. electrodes	49 mph	Track dry/car dry/ device dry	Vehicle stopped, restarted (hot start).	None
21	Nissan Pathfinder	Ac powered	Generator powered, 6-in. electrodes	34 mph	Track dry/car dry/ device dry	Lost power but idled. Popped clutch & took off.	None
22	Nissan Maxima	Ac powered	Generator powered, 6-in. electrodes	65 mph	Track dry/car dry/ device dry	Vehicle stopped, stumbled at restart. On 3rd start, restarted (hot start).	None
23	Ford Aerostar (white)	Ac powered	Generator powered, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Vehicle stopped, no start (hot start). Key cycle, restarted.	None
24	Ford Aerostar (white)	Ac powered	Generator powered, 6-in. electrodes	56 mph	Track dry/car dry/ device dry	Vehicle stopped, no start (hot start). Key cycle, no start.	EEC, ignition-control module
25	Chevy Blazer	Ac powered	Generator powered, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Sputter, no stop.	None
26	Chevy Blazer	Ac powered	Generator powered, 1-ft screen electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Stumble, no stop (ABS brake light on, reset with key).	None
27	Chevy Blazer	Ac powered	Generator powered, 1-ft screen electrodes	58 mph	Track dry/car dry/ device dry	Vehicle stopped, no restart (hot start). Key reset started, rough idle.	None
28	Chevy Blazer	Ac powered	Generator powered, 1-ft screen electrodes	38 mph	Track dry/car dry/ device dry	Vehicle stopped, no restart (hot start). Key reset, restarted.	None
29	Chevy Blazer	Ac powered	Generator powered, 10-in. electrodes (3-in. springs)	63 mph	Track dry/car dry/ device dry	No stop.	Battery recharge
30	Dodge Spirit	Ac powered	Generator powered, 6-in. electrodes	60 mph	Track dry/car dry/ device dry	Stumble, no stop.	None
31	Dodge Spirit	Ac powered	Generator powered, 6-in. electrodes	40 mph	Track dry/car dry/ device dry	Vehicle stopped, no restart.	Radiator fan motor, engine-control computer (SMEC)

Table B-1. Full shot record of test period (cont'd).

Shot no.	Vehicle	Device	Comments	Vehicle speed	Conditions	Results	Vehicle damage (repair shop)
32	Chevy Pickup	Ac powered	Generator powered, 6-in. electrodes	60 mph	Track dry/car dry/ device dry	Vehicle stopped, no restart.	PCM, ignition-control module, distributor pickup
33	Honda Accord EX	Ac powered	Generator powered, 6-in. electrodes	61 mph	Track dry/car dry/ device dry	Vehicle stopped, no restart (hot start). Key cycle, restart.	None
34	Honda Accord EX	Ac powered	Generator powered, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Stumble, no stop.	None
35	Honda Accord EX	Ac powered	Generator powered, 6-in. electrodes	40 mph	Track dry/car dry/ device dry	Stumble, no stop.	None
36	Honda Accord EX	Ac powered	Generator powered, 6-in. electrodes	59 mph	Track dry/car dry/ device dry	No stop. Loss of power, recovered after 30 s.	None
37	Pontiac Firebird	Ac powered	Generator powered, 6-in. electrodes	56 mph	Track dry/car dry/ device dry	Vehicle stopped, no clutch start. Restart on key cycle. Smoke in dash.	None
38	Pontiac Firebird	Ac powered	Generator powered, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Stumble, no stop.	None
39	Pontiac Firebird	Ac powered	Generator powered, 6-in. electrodes	38 mph	Track dry/car dry/ device dry	Stumble, no stop.	None
40	Pontiac Firebird	Ac powered	Generator powered, 6-in. electrodes	60 mph	Track dry/car dry/ device dry	Small stumble, no stop.	Alternator
41	Ford Aerostar (green)	Ac powered	Generator powered, 6-in. electrodes	Standing start (45 ft)	Track dry/car dry/ device dry	Vehicle stopped, no restart.	EEC
42	Ford Taurus	Ac powered	Generator powered, 6-in. electrodes	59 mph	Track dry/car dry/ device dry	Vehicle stopped, no restart.	Ignition-control module, EEC
43	Nissan Maxima	Ac powered	Generator powered, 6-in. electrodes	Field map	Track dry/car dry/ device dry	Field map shots 43–51. Data bad, fiber optics not working.	None

SMEC = single-module engine controller

EEC = electronic engine control

PCM = power-train control module

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13. ABSTRACT *(Maximum 200 words)*

This report discusses the results of phase III of the Electrical Vehicle Stopper Evaluation (EVSE) program of the Nonlethal Technologies, Inc., Road Sentry vehicle stopper device. The Road Sentry injects a large current pulse directly into the underside of the vehicle and stops the vehicle by damaging the electrical components. This report also discusses the field evaluation of safety, ease of use, and effectiveness of the device.

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